3.6.1.3 Natural Resources, Canada (NRCan)

Background

Natural Resources Canada (NRCan) acts as an International Terrestrial Reference System (ITRS) combination center for the International Earth Rotation and Reference Systems Service (IERS). This contribution focuses on its International Terrestrial Reference Frame (ITRF) activities for 2003. The IERS objective for the TRF combination project is to have independent rigorous combinations of the TRF realization; thus providing much needed quality control. The long-term objective is to eventually produce routine weekly inter-technique (DORIS, GPS, SLR and VLBI) combinations. At NRCan, the capability to combine GPS solutions has been developed in the late 1990s and is used to routinely produce weekly solutions for the International GPS Service (IGS). The production of combined weekly inter-techniques solutions is a natural extension of the existing software capabilities.

Software Enhancements

The existing software uses the SINEX format version 1.00 directly. A modular approach was originally adopted for the software development. In its current form, the software can perform various operations on SINEX files such as: Helmert transformation, combination, comparison, etc. In their current form, the modules can handle station coordinates/velocities and ERPs (pole position/rate and length of day) along with the available covariance information using standard least-squares algorithms. Some flexibility in the format specifications allows the solutions to be made available in different SINEX "flavors". Within IGS, the files are transformed in a consistent "flavor" of the format using auxiliary information, a few computer environment commands and a preprocessor program. Before extending the software to accept the version 2.00 format, it was decided to attempt inter-techniques combination with the existing software. This was also useful to gain more experience with the solutions from the other techniques and produce some results in a timely manner. With this "temporary" approach, the required enhancements were mainly concentrated at the pre-processing stage. One preprocessor was tailored to each center solution.

Data Analysis

The original data analysis objective was to generate a combined solution for the station coordinates/velocities and ERPs using each technique solution for 1999. The analysis reported below was prepared for and presented at the European Geophysical Society 2003 conference in Nice. Due to the absence of technique solutions (except for the combined IGS solution and DORIS with only one solution available), it was decided to use a subset of the solutions available from the techniques (solution acronyms and responsible agency):

1) VLBI:
   – BKG: Bundesamt für Kartographie und Geodäsie
   – GSFD: Goddard Space Flight Center
   – NGL: Deutsches Geodätisches Forschungsinstitut
2) SLR:
   – ASI: Agenzia Spaziale Italiana
   – DGFI: Deutsches Geodätisches Forschungsinstitut
   – JCET: Joint Center for Earth Systems Technology
3) DORIS:
   – IGN: Institut Géographique National
4) GPS:
   – IGS: International GPS Service

In this combination test, the pole rates and LOD/UT parameters were not combined. The combinations of the pole rates are not expected to cause any special problems. Those are routinely included in the IGS combination. The combination of the LOD/UT may require special attention. Unused parameters were discarded after the solutions were unconstrained (when applicable). The combination process was done in two steps: an intra-technique combination and an inter-technique combination. This approach has been chosen because it is less demanding on the available resources, namely, existing software is usable with minimal upgrades. However, this approach introduces some approximations.

In the first combination step, an intra-technique combination for each technique was done on the selected VLBI (BKG, GSFD, NGL) and SLR (ASI, DGFI, JCET) Analysis Centres (ACs) solutions. Those could be processed as SINEX version 1.00. In this step, the following activities were performed: 1) standardization of the solutions to a consistent “flavor” of SINEX, 2) removal of the constraints & rescale covariance (iterative), 3) removal of the outliers (also iterative), 4) alignment of all solutions to a reference using 14 or less transformation parameters (rotation, translation, scale & rates) as appropriate, 5) combination (addition of normals) and 6) analysis of the results. The solutions for 1999 AC test solutions were combined in 13 distinct solutions, each one covering 28 days. Since the IGS solution was already the result of the combination of 7 ACs (COD, EMR, ESA, GFZ, JPL, NGS, SIO), the weekly solutions were simply combined into monthly solutions. Table 1 shows a summary of the statistics for each Analysis Center selected within each technique. Several iterations were required for the ACs within the VLBI and SLR techniques to resolve various problems and to remove outliers. The exercise showed that there is some room for improvement in the test solutions available. The GPS solutions were combined from the original ACs contributions, which were provided for the IGS SINEX combination Pilot Phase. All the solutions were aligned to but not constrained to ITRF2000.

Table 1: Average and standard deviations of the ACs after the intra techniques (VLBI/SLR/GPS) combinations for the coordinates and pole position residuals for the 1999 observations.

Technique Center	**N(mm) x/σ**	**E(mm) x/σ**	**H(mm) x/σ**	**Xp(µas) x/σ**	**Yp(µas) x/σ**
VLBI					
BKG	0.2/1.2	0.0/1.2	0.0/4.0	15/181	-15/235
GSFD	-0.2/1.2	0.0/1.1	0.0/3.0	15/151	-36/188
NGL	-0.5/6.7	-0.1/5.9	0.0/8.9	-56/310	170/277
SLR					
ASI	-0.7/7.1	0.0/5.7	0.0/18.5	51/177	8/123
DGFI	0.0/7.7	0.0/8.3	0.0/7.1	-33/416	-29/345
JCET	0.1/6.2	0.0/5.1	0.0/6.5	-12/336	19/321
GPS					
COD	1.2/2.6	0.0/3.2	-0.02174	-26/99	38/107
EMR	-3/6.7	0.8/8.2	0.2/12.2	95/187	34/202
ESA	-2.5/5.1	0.0/7.3	0.0/12.8	3/20	-20/24
GFZ	0.0/2.7	0.0/3.0	0.6/8.6	-5/58	63/70
JPL	-0.4/3.1	-0.1/3.7	0.4/8.8	7/77	3/88
NGS	-1.7/5.2	0.7/6.5	0.6/10.3	-22/296	109/283
SIO	-1.9/3.6	-0.8/4.8	-0.3/10	-26/109	40/91

Figures 1, 2 and 3 show time series of residuals for the X and Y pole positions between the combined solutions for each technique (VLBI, SLR, GPS) and the respectively selected ACs.

In the second step, an inter-technique combination was performed using 3 techniques for a solution and the relevant inter-technique local ties. Due to some instability in the alignment of the monthly solutions for VLBI, they have not been included here. It requires further analysis. Comparison of the combined solution coordinates and ITRF2000 shows RMS in the north, east and height axis of 5.9 mm, 8.9 mm and 9.5 mm respectively at the solutions epoch. Figure 4 shows the ERP's residuals between the combined solution and the GPS/SLR/DORIS techniques.

The DORIS combination, which includes only the IGN solutions, is significantly noisier than the SLR and GPS solutions. Even between GPS and SLR, there are apparent noise level differences. This causes the GPS solution to dominate the pole position combination. The combined pole positions results were then compared to Bulletin A (see Figure 5 for the time series of the differences). The noise level is about 0.1 mas for both components. There is no significant bias between the pole position series for the X component. However, there is an average bias of about 0.18 mas for the Y component.

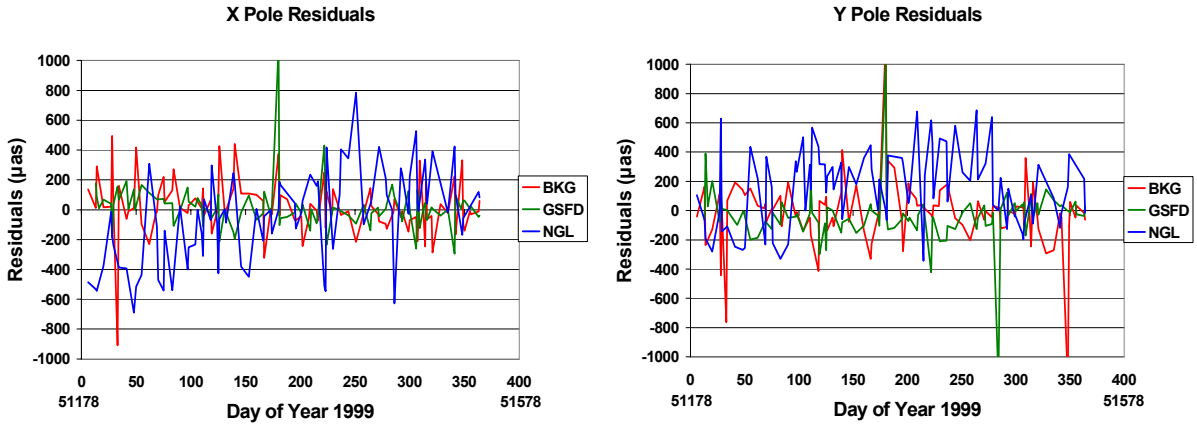

Fig. 1: VLBI combined X&Y pole position minus ACs estimates

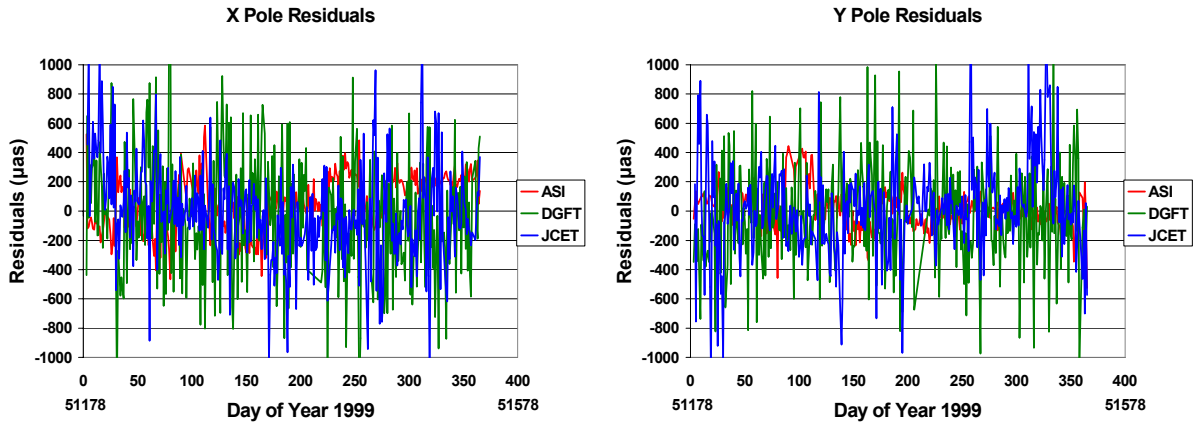

Fig. 2: SLR combined X&Y pole position minus ACs estimates

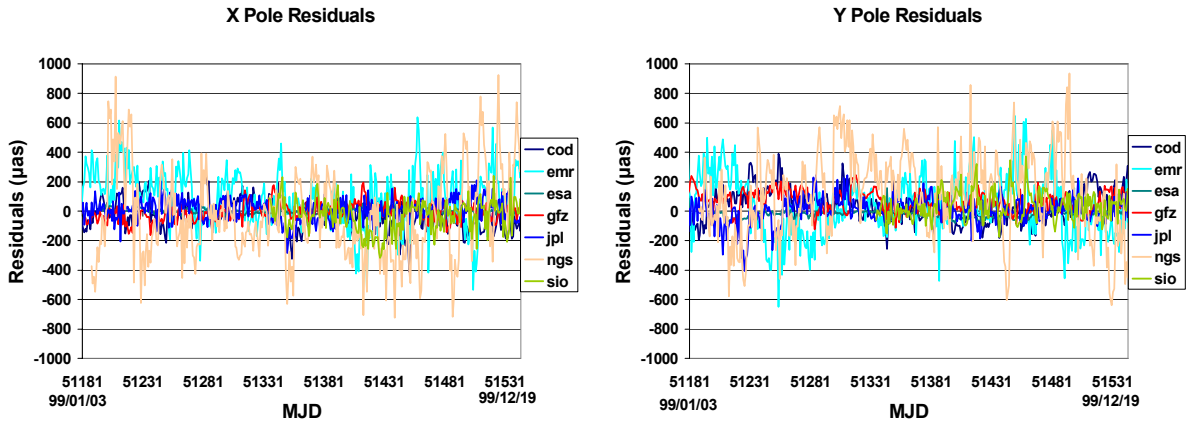

Fig. 3: IGS combined daily X&Y pole position minus ACs estimates

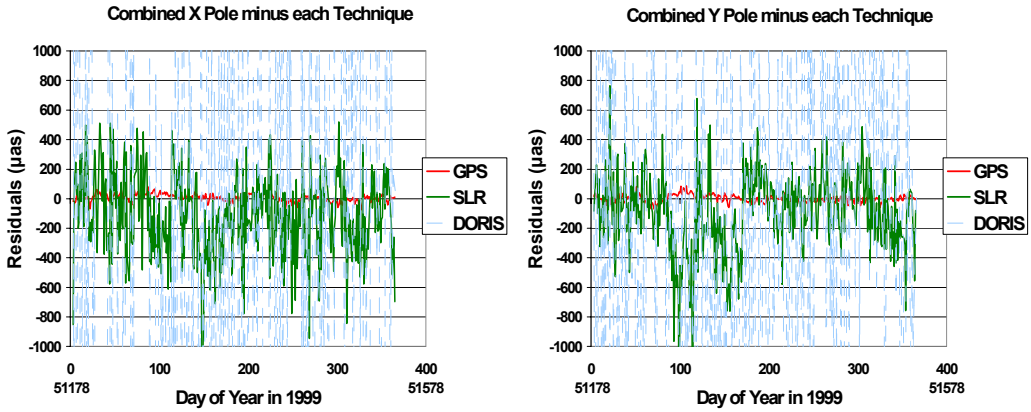

Fig. 4: Residuals between the combined (GPS/SLR/DORIS) and each technique

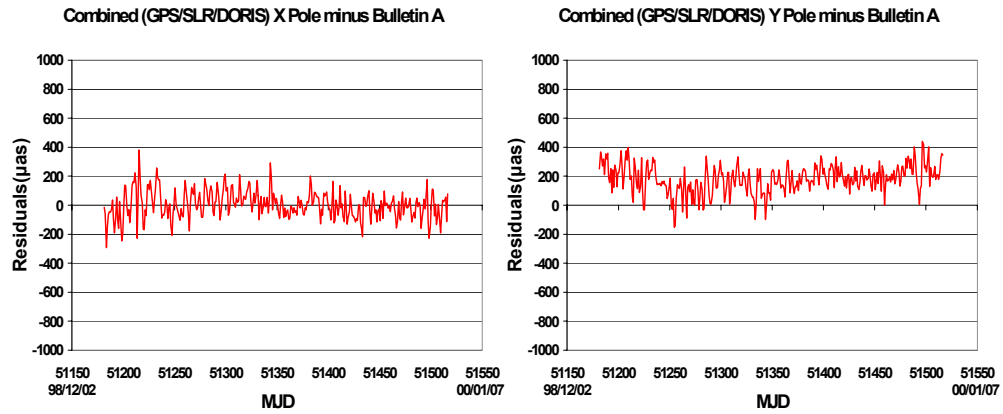

Fig. 5: Comparison of the combined pole position with respect to Bulletin A

Future Work

The short to medium term activities related to the TRF combination at NRCan will be concentrated in completing the analysis and extending the software capabilities. The combination effort on the 1999 test observations has so far indicated that there are still problems within the techniques. For example there are many station coordinates inconsistencies leading to outliers, as well as formatting and unconstraining issues. Solution consistencies can certainly best be resolved by/within each technique.

Rémi Ferland